# CARBON NANOTUBE-BASED VACUUM AND SEMICONDUCTING DEVICES FOR MICRO-INSTRUMENTATION AND ELECTRONICS


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**Introduction:** High-current density field emission electron sources are the essential components to enable multiple miniature instruments for planetary probe missions, which include, XRD/XRF, XPS, miniature mass spectrometers, UV-Lasers for Raman spectroscopy, advanced THz sources for heterodyne spectroscopy, and vacuum microelectronics. Such sources increase the data collection rate, and reduce mass and power budgets, which makes them attractive for probe missions, especially to extreme environments such as Venus, where the mission lifetime could be very short.

Carbon nanotube (CNT)-based electronics are inherently radiation hard and find applications in high frequency as well as in control and communication electronics. It is possible to realize logic gates and zero-power consuming non-volatile memories using CNTs that can be employed for electronic applications in probe missions to high radiation Jovian environment.

This work focuses on the field emission and the electronics technology development using both multi-walled nanotubes (MWNTs) and single-walled nanotubes (SWNTs).

**CNT Field Emitters:** On the field emitter front, the high-current-density CNT bundle arrays have been developed and have been successfully integrated with extraction grids using either molybdenum or conductive silicon-on-insulator substrates. The recent Mo-gate samples have produced current densities > 4 A/cm$^2$ at the anode with emission efficiencies up to 95%. Further electron beam optics design and fabrication considerations will be shown.

**CNT Schottky Dodes:** In the CNT-Schottky diode development, we have produced devices with Pt or Pd Ohmic contacts and Ti Schottky contacts using angled evaporation technique. After annealing the devices have exhibited ideality factors (n) of 1.3 to 1.5. They still suffer from hundreds of kOhms series resistance and the aging effect when tested after a prolonged storage. Again, annealing was seen to restore/improve the device performance. Details of these results along with their application modes for planetary probe missions will be discussed.